CLAIMS

We claim:

1. A method of producing neutrons in a chamber containing an ion source region, an accelerator region and a gas target region, comprising the steps of;

   a. generating deuterium ions in the ion source region,
   b. accelerating deuterium ions to high-energy by the application of an electric field in the accelerator region,
   c. allowing deuterium ions to collide with deuterium gas targets in the gas target region, producing neutron-generating fusion reactions.

2. The method according to claim 1 wherein the gas targets are replenishable.

3. The method according to claim 1 further comprising the step of placing the chamber in an inactive state in which state neutron-generating fusion reactions do not occur.

4. The method according to claim 1 wherein the deuterium gas targets comprise a mixture of deuterium and tritium gas for high-energy neutron generation.

5. The method according to claim 1 wherein the ion source comprises an ion source selected from the group consisting of a Penning ion source, a plasmatron, a duoplasmatron, a radio frequency ion source, a quadrapole ion source, and a discharge ion source.

6. The method according to claim 1 further comprising the step of minimizing the production and transmission of electrons through the accelerator region.

7. The method according to claim 6 wherein the step of minimizing the production and transmission of electrons through the accelerator region provides greater neutron generation per unit ion current than that prior to the step of minimizing.

8. A single-cathode high-pressure high-resistance gaseous discharge neutron producing apparatus, comprising:

a) a vacuum chamber,
b) an anode electrode located within said vacuum chamber having an anode electrode surface,
c) a cathode electrode located within said vacuum chamber, wherein the cathode is comprised of at least one surface that is semi-transparent to nuclear and atomic particles, wherein said at least one semi-transparent surface determines a preferred direction of particle motion that is generally perpendicular to said at least one surface, said at least one cathode surface defining an intra-cathode region whereby particles may penetrate the at least one semi-transparent surface and traverse the intra-cathode region, said cathode surfaces further being adjacent to an anode-cathode gap region lying between the anode electrode and cathode electrode surfaces,
d) a gas orifice for controllably introducing fusible deuterium gas into the vacuum chamber, and a pump orifice for controllably evacuating said vacuum chamber, and
e) a controller for regulating the operation of a high-pressure high-resistance gaseous discharge within the vacuum chamber, including a voltage supply for controllably applying a negative high-voltage to said cathode electrode relative to the anode electrode, and for controllably allowing the passage of current.

9. The apparatus according to claim 8 further comprising a pressure sensor for monitoring a gas pressure within the vacuum chamber.

10. The apparatus according to claim 8 wherein the cathode further comprises at least one non-transparent surface for impeding the movement of gaseous discharge particles.

11. The apparatus according to claim 8, wherein the at least one semi-transparent surface of the cathode comprises a plurality of openings that are sufficiently large so as to not significantly inhibit the movement of ions and fast neutral particle products of a gaseous discharge from passing through said openings.

12. The apparatus according to claim 8 wherein the deuterium gas comprises a gas mixture including tritium gas.

13. The apparatus according to claim 8 wherein the anode electrode is comprised of an inner surface of the vacuum chamber.

14. The apparatus according to claim 8 wherein the anode electrode comprises openings and is semi-transparent to nuclear and atomic particles.

15. The apparatus according to claim 8 wherein the gas orifice and pump orifice share a common opening to an interior cavity of the vacuum chamber.

16. The apparatus according to claim 8, further comprising a gas pressure storage and regulation mechanism for storing at least a portion of the deuterium gas and for regulating the pressure of the deuterium gas in the vacuum chamber.

17. The apparatus according to claim 16 wherein the gas pressure storage and regulation mechanism comprises a getter material.

18. The apparatus according to claim 8 further comprising a heat removal facility for preventing heat damage to the apparatus.

19. The apparatus according to claim 8 wherein the anode and cathode are cylindrical in shape having cylinder wall surfaces, with a ratio of the intra-cathode region length to diameter greater than 1, the cathode is aligned to be concentric within the anode, and the

cylinder wall surfaces of the cathode are semi-transparent and the resultant particle flow direction is generally radial with respect to the centerline of the cathode, whereby fusion collisions that produce neutrons occur primarily throughout the cylindrical volume of the discharge, creating a neutron source that is substantially linear.

20. The apparatus according to claim 8 wherein the anode and cathode are cylindrical in shape, having cylinder wall surfaces, with a ratio of intra-cathode region length to diameter less than or equal to 1, the cathode is aligned to be concentric within the anode, the cylinder wall surfaces of the cathode are semi-transparent and the resultant particle flow direction is substantially radial with respect to the centerline of the cathode, whereby fusion collisions that produce neutrons occur throughout the cylindrical volume of the discharge, creating a neutron source that is substantially disc-shaped and planar.

21. The apparatus according to claim 8 wherein the anode and cathode are each formed in a right rectangular prism shape with a length to height ratio and width to height ratio of the intra-cathode region sufficiently large so that two of its prism faces that are larger than the other four faces, and wherein at least two faces of the cathode prism are semi-transparent and the resultant direction of particle motion is generally along the length, width, or height of the device, whereby fusion collisions that produce neutrons occur throughout the volume of the discharge, creating a substantially planar section neutron source.

22. The apparatus according to claim 8 wherein the diameter of a central hole of the vacuum chamber is large enough to place material to be irradiated therein, the anode and cathode are annular in shape, concentric with each other having flat sections that are non-transparent, and wherein curved surfaces of the cathode are semi-transparent and the resultant particle flow direction is generally radial with respect to a central axis of the central opening that passes through the vacuum chamber, normal to the curved surfaces of the cathode, whereby fusion collisions that produce neutrons occur substantially throughout the volume of the discharge, creating a neutron flux at the central hole for irradiation of material.

23. The apparatus according to claim 8 further comprising an electron management system to augment neutron production power efficiency of the neutron producing apparatus by reducing power consumption attributable to electrons generated in the vacuum chamber.

24. The apparatus according to claim 23 wherein the electron management system comprises a feature selected from the group consisting of electrode surface treatments and low-secondary electron emission materials to reduce secondary electron formation.

25. The apparatus according to claim 23 wherein the electron management system provides electric potential repression of the intra-cathode region to reduce secondary electron formation.

26. The apparatus according to claim 23 wherein the electron management system comprises baffle electrodes to minimize intra-cathode region errant particle and electron paths for minimization of electron generation.

27. The apparatus according to claim 23 wherein the electron management system comprises the placement of surfaces to promote electron-ion recombination within the intra-cathode region to minimize power losses.

28. A method of producing neutrons in a chamber containing an anode electrode and a semi-transparent cathode electrode comprising the steps of;

introducing a fusible gas into the vacuum chamber;

creating a voltage differential between the cathode electrode and the anode electrode whereby a high-pressure high-resistance gaseous discharge forms primarily between the anode electrode and at least one semi-transparent surface of the cathode electrode and extends through openings of the semi-transparent cathode into an intra-cathode region defined by at least one surface of the cathode electrode, and whereby ions selected from the group consisting of deuterium ions and tritium ions of said discharge are accelerated

by said voltage differential, with a substantial portion of said ions passing through the openings of the semi-transparent cathode surfaces;

allowing a portion of said ions to undergo charge-exchange collisions with background gas particles to produce fast-neutral particles selected from the group consisting of deuterium particles and tritium particles, whereby a portion of said fast neutral particles pass through the openings of the semi-transparent cathode surfaces, and whereby said high-resistance gaseous discharge is sustained primarily through charged particle generation initiated by the ions and fast neutral particles; and

generating neutrons from said high-pressure high-resistance gaseous discharge predominantly as a product of fusion collisions occurring between said ions and background gas particles and between said fast-neutral particles and background gas particles.

29. The method according to claim 28 wherein at least a portion of background gas particles that experience collisions with ions or fast-neutral particles are situated on a surface of a material within the vacuum chamber at the time that they experience the collisions.

30. The method according to claim 29, wherein the portion of background gas particles that are situated on a surface of a material within the vacuum chamber are attached to the surface by chemical adsorption.

31. The method according to claim 29, wherein the portion of background gas particles that are situated on a surface of a material within the vacuum chamber are attached to the surface by physical adsorption.

32. The method according to claim 28, wherein the chamber and electrodes have a shape selected to produce neutrons with a spatial distribution dependent on the high-pressure high-resistance discharge volume within the shape.

33. The method according to claim 28 wherein the chamber further comprises an electron management system to augment neutron production power efficiency of the method by reducing power consumption attributable to electrons generated in the vacuum chamber and conducted through the gaseous discharge.

34. The method according to claim 33 wherein the electron management system comprises a feature selected from the group consisting of electrode surface treatments and low-secondary electron emission materials to reduce secondary electron formation.

35. The method according to claim 33 wherein the electron management system provides electric potential repression of the intra-cathode region to reduce secondary electron formation.

36. The method according to claim 33 wherein the electron management system comprises baffle electrodes to minimize intra-cathode region errant particle and electron paths for minimization of electron generation.

37. The method according to claim 33 wherein the electron management system comprises the placement of surfaces to promote electron-ion recombination within the intra-cathode region to minimize power losses.

38. The method according to claim 28 wherein the cathode further comprises at least one non-transparent surface for impeding the movement of gaseous discharge particles.

39. The method according to claim 28 wherein the at least one semi-transparent surface of the cathode comprises a plurality of openings that are sufficiently large so as to allow passage of ions and fast neutral particles.

40. The method according to claim 28 wherein the anode electrode is comprised of an inner surface of the vacuum chamber.

41. The method according to claim 28 wherein the anode electrode comprises openings and is semi-transparent to nuclear and atomic particles.

42. The method according to claim 28 wherein the chamber further comprises a gas pressure storage and regulation mechanism for storing at least a portion of the deuterium gas and for regulating a pressure of the deuterium gas in the vacuum chamber.

43. The method according to claim 28 further comprising the step of storing at least a portion of the deuterium gas and regulating a pressure of the deuterium gas using a getter material.

44. The method according to claim 28 wherein the chamber further comprises a heat removal mechanism for preventing heat damage to the chamber.

45. A double-cathode high-pressure high-resistance gaseous discharge neutron producing apparatus comprising:

a vacuum chamber;

an anode electrode located within said vacuum chamber;

an electron-suppressor cathode electrode located within said vacuum chamber comprised of at least one semi-transparent surface that determines a predominant direction of particle motion generally perpendicular to said surface, said surface bordering an intra-cathode region bounded by surfaces of the electron-suppressor cathode electrode, and an anode-cathode gap region within the vacuum chamber between the anode electrode and the electron-suppressor cathode electrode, wherein openings in said at least one semi-transparent surface of the suppressor electrode allow ions and fast neutral particles within the chamber to pass into and out of the intra-cathode region;

a leeching cathode electrode located within said intra-cathode region, having at least one semi-transparent surface having openings to allow nuclear and atomic particles to move through said surface, wherein a surface of the leeching cathode electrode borders a leeching-

suppressor gap region lying between said leeching cathode electrode and said suppressor electrode surfaces, wherein openings in said semi-transparent surfaces of the leeching electrode allow the passage of nuclear and atomic particles through the leeching-suppressor gap region, and wherein a portion of the openings of the semi-transparent leeching electrode are aligned with a portion of openings of the semi-transparent suppressor electrode so as to provide particle paths through both the suppressor and leeching cathode electrodes, and wherein the openings in said semi-transparent surfaces of the leeching electrode are sufficiently large so to allow the passage of ions and fast neutral particles;

a leeching electrode power supply for controllably applying a voltage to said leeching electrode relative to the anode, and for controlling an amount of power delivered to the leeching electrode

a suppressor electrode power supply for controllably applying a voltage to said suppressor electrode relative to the anode, and for controlling the amount of power delivered to the suppressor electrode; and

a gas orifice for controllably introducing fusible deuterium gas into the vacuum chamber, and a pump orifice for controllably evacuating said vacuum chamber.

46. The apparatus of claim 45 further comprising a controller for regulating the operation of a high-pressure high-resistance gaseous discharge within the vacuum chamber, including a voltage supply for controllably applying negative high-voltages to said cathode electrodes relative to the anode electrode, and for controllably allowing the passage of current.

47. The apparatus according to claim 46 further comprising a pressure sensor for monitoring gas pressure within the vacuum chamber.

48. The apparatus according to claim 46 wherein the electron-suppressor cathode electrode comprises at least one non-transparent surface to prevent gaseous discharge particles from moving through said non-transparent surface.

49. The apparatus according to claim 46 wherein the leeching cathode electrode comprises at least one non-transparent surface to prevent particles from moving through said non-transparent surface.

50. The apparatus according to claim 46 wherein the leeching electrode power supply and suppressor electrode power supply comprise a first power supply for controllably applying a voltage to said leeching electrode relative to the anode and for controllably applying a voltage to said suppressor electrode relative to the anode, and a second power supply for applying an additional bias to the suppressor electrode.

51. The apparatus according to claim 46, wherein the at least one semi-transparent surface of the cathode comprises a plurality of openings that are sufficiently large so as to not significantly inhibit the movement of ions and fast neutral particle products of a gaseous discharge from passing through said openings.

52. The apparatus according to claim 46 wherein the deuterium gas comprises a gas mixture including tritium gas.

53. The apparatus according to claim 46 wherein the anode electrode is comprised of an inner surface of the vacuum chamber.

54. The apparatus according to claim 46 wherein the anode electrode comprises openings and is semi-transparent to nuclear and atomic particles.

55. The apparatus according to claim 46 wherein the gas orifice and pump orifice share a common opening to an interior cavity of the vacuum chamber.

56. The apparatus according to claim 46, further comprising a gas pressure storage and regulation mechanism for storing at least a portion of the deuterium gas and for regulating the pressure of the deuterium gas in the vacuum chamber.

57. The apparatus according to claim 56 wherein the gas pressure storage and regulation mechanism comprises a getter material.

58. The apparatus according to claim 46 further comprising a heat removal mechanism for preventing heat damage to the apparatus.

59. The apparatus according to claim 46 wherein the anode and cathodes are cylindrical in shape having cylinder wall surfaces, with a ratio of the intra-cathode region length to diameter greater than 1, and wherein the cathodes are aligned concentrically within the anode, the cylinder wall surfaces of the cathodes are semi-transparent such that the resultant particle flow direction is substantially radial with respect to the centerline of the cathode, whereby fusion collisions that produce neutrons occur substantially throughout the cylindrical volume of the discharge, creating a neutron source that is effectively linear.

60. The apparatus according to claim 46 wherein the anode and cathodes are cylindrical in shape with a ratio of intra-cathode region length to diameter of less than or equal to 1, the cathodes are aligned concentrically within the anode, and the cylindrical curved surfaces of the cathodes are semi-transparent such that the resultant particle flow direction is substantially radial with respect to the centerline of the cathode, whereby fusion collisions that produce neutrons occur throughout the cylindrical volume of the discharge, creating a neutron source that is substantially disc-shaped and planar.

61. The apparatus according to claim 46 wherein the anode and cathodes are shaped as right rectangular prisms having a length to height ratio and width to height ratio of the intra-cathode region sufficiently large so that two prism faces are larger than the other four faces, at least two faces of each cathode prism are semi-transparent such that the resultant direction of particle motion is substantially along the length, width, or height of the apparatus, whereby fusion collisions that produce neutrons occur throughout the volume of the discharge, creating a substantially planar section neutron source.

62. The apparatus according to claim 46 wherein a diameter of a central hole of the vacuum chamber is sufficiently large to contain material to be irradiated, the anode and cathodes are annular in shape, concentrically arranged with respect to each other with flat sections that are non-transparent, the curved surface of the cathodes being semi-transparent such that the resultant particle flow direction is substantially radial with respect to a central axis of the central hole that passes through the vacuum chamber, normal to the curved surfaces of the cathode, whereby fusion collisions that produce neutrons occur throughout the volume of the discharge, creating a neutron flux at the central hole for the irradiation of material.

63. The apparatus according to claim 46 further comprising an electron management system to augment neutron production power efficiency of the neutron producing apparatus by reducing power consumption attributable to electrons generated in the vacuum chamber.

64. The apparatus according to claim 63 wherein the electron management system comprises a feature selected from the set consisting of electrode surface treatments and the use of low-secondary electron emission materials to reduce secondary electron formation.

65. The apparatus according to claim 63 wherein the electron management system provides electric potential repression of the intra-cathode region to reduce secondary electron formation.

66. The apparatus according to claim 63 wherein the electron management system comprises baffle electrodes to minimize intra-cathode region errant particle and electron paths for minimization of electron generation.

67. The apparatus according to claim 63 wherein the electron management system comprises the placement of surfaces to promote electron-ion recombination within the intra-cathode region to minimize power losses.

68. A method of producing neutrons in a chamber containing an anode electrode, a semi-transparent suppressor cathode electrode and a semi-transparent leeching cathode comprising the steps of;

introducing a fusible gas into the vacuum chamber;

creating a voltage differential between the cathode electrodes and the anode electrode, and applying a high-voltage to the leeching cathode, and a bias voltage to the suppressor electrode relative to the leeching cathode, whereby a high-pressure high-resistance gaseous discharge forms primarily between the anode and semi-transparent suppressor surfaces and extends through the openings of the semi-transparent suppressor electrode surfaces, passing through the suppressor and leeching electrodes and an intra-cathode region defined by at least one surface of the cathode electrode, and whereby ions selected from the group consisting of deuterium ions and tritium ions of said gaseous discharge are accelerated by the voltage differential, with a substantial portion of said ions passing through the openings of the semi-transparent cathode surfaces;

allowing a portion of said ions to undergo charge-exchange collisions with background gas particles to produce fast-neutral particles selected from the group consisting of deuterium particles and tritium particles, whereby a portion of said fast-neutral particles pass through the openings of the semi-transparent cathode surfaces, and whereby said high-pressure high-resistance gaseous discharge is sustained primarily through charged particle generation initiated by the ions and fast neutral particles; and

generating neutrons from said high-pressure high-resistance gaseous discharge as a product of fusion collisions occurring between said ions and background gas particles and between said fast-neutral particles and background gas particles.

69. The method according to claim 68 wherein at least a portion of background gas particles that experience collisions with ions or fast-neutral particles are situated on a surface of a material within the vacuum chamber at the time that they experience the collisions.

70. The method according to claim 69, wherein the portion of background gas particles that are situated on a surface of a material within the vacuum chamber are attached to the surface by chemical adsorption.

71. The method according to claim 69, wherein the portion of background gas particles that are situated on a surface of a material within the vacuum chamber are attached to the surface by physical adsorption.

72. The method according to claim 68, wherein the chamber and electrodes have a shape selected to produce neutrons with a spatial distribution dependent on the high-pressure high-resistance discharge volume within the shape.

73. The method according to claim 68, further comprising the step of employing an electron management system to augment the neutron production power efficiency of the method through the reduction of power consumed by the production or conduction of electrons through the gaseous discharge.

74. The method according to claim 73 wherein the electron management system comprises a feature selected from the set consisting of electrode surface treatments and the use of low secondary electron emission materials to reduce secondary electron formation.

75. The method according to claim 73 wherein the electron management system provides electric potential repression of the intra-cathode region to reduce secondary electron formation.

76. The method according to claim 73 wherein the electron management system comprises baffle electrodes to minimize intra-cathode region errant particle and electron paths for minimization of electron generation.

77. The method according to claim 73 wherein the electron management system comprises the placement of surfaces to promote electron-ion recombination within the intra-cathode region to minimize power losses.

78. A self-contained, portable bulk material on-line analysis system for measuring the elemental content and determining physical properties of subject material comprising:

a gas-target neutron generator system to controllably provide neutrons for the analysis of the subject material;

a radiation detector situated proximally to the subject material for collecting secondary radiation caused by the impingement of neutrons on the subject material;

a data acquisition system to receive information from said detector, and to determine a property of the subject material based on the information received from said detector.

79. The system according to claim 78, wherein the neutrons interact with substantially the entire volume of the subject material, providing direct scanning of all the subject material rather than a sampling of only a portion of the subject material.

80. The system according to claim 78 further comprising a series of moderating materials selected and positioned to slow neutrons to appropriate energies for interaction with the subject material.

81. The system according to claim 78 wherein the data acquisition system utilizes wireless data transmission and acquisition for remote on-line analysis.

82. The system according to claim 78, further comprising an electronic control system for independent operation without a human operator present.

83. The system according to claim 78, wherein the gas target neutron generator is a single-cathode high-pressure high-resistance gaseous discharge neutron generator.

84. The system according to claim 78, wherein the gas-target neutron generator is a double-cathode high-pressure high-resistance gaseous discharge neutron generator.

85. The system according to claim 78, wherein the radiation detector comprises an array of detectors placed proximally to the subject material for detection resolution, for providing a feature selected from the set consisting of spatial imaging and the detection of prompt and delayed radiation.

86. The system according to claim 78, further comprising an interface to modify a process involving the subject material based on the determined property of the subject material.

87. The system according to claim 86, wherein the interface utilizes an industrial control system to direct an industrial process.

88. The system according to claim 86, wherein the interface utilizes a software algorithm for evaluating the determined properties of the subject material and directing a course of action.

89. The system according to claim 78, further comprising a mechanism for controlling multiple such systems in concert.

90. The system according to claim 89, further comprising a data acquisition and control system that utilizes data and determines properties from multiple analysis systems to direct one or more industrial processes.

91. The system according to claim 78, wherein the radiation detector detects gamma rays.

92. The system according to claim 78, wherein the radiation detector detects neutrons that are either reflected, scattered, thermalized or attenuated by the subject material.

93. The system according to claim 78, further comprising conveyance means to move the subject material relative to the neutron generator.

94. The system according to claim 93, wherein the conveyance means comprises a conveyor belt.

95. The system according to claim 94, wherein the neutron generator comprises a long cylindrical high-pressure high-resistance gaseous discharge neutron generator to produce a substantially linear neutron distribution for substantially uniformly irradiating the conveyor width for effecting scanning and detection substantially across the entire conveyor width.

96. The system according to claim 94, wherein the neutron generator comprises a rectangular prism shaped high-pressure high-resistance gaseous discharge neutron generator to produce a substantially planar neutron distribution for effecting uniform conveyor area scanning and detection.

97. The system according to claim 93, wherein the conveyance means comprises a conveyance selected from the group consisting of a pipe, duct and chute.

98. The system according to claim 97, wherein the neutron generator comprises an annular high-pressure high-resistance gaseous discharge neutron generator to produce a substantially uniform neutron distribution for substantially uniform pipe scanning and detection resolution.

99. The system according to claim 78, further comprising an exterior container with radiation shielding to protect an external worker environment and to minimize signal noise to the radiation detector.

100. The system according to claim 78, wherein the determined property of the subject material is selected from the group consisting of density, porosity, thickness, chemical composition, moisture content, and flow velocity, for an application.

101. The system according to claim 100, wherein the application is coal quality analysis, for determining a property selected from the group consisting of heating value, ash quality and content, moisture content, sulphur content, mercury content, sodium content, and chlorine content.

102. The system according to claim 100, wherein the application is metals mining quality analysis, for determining metal ore and residual material concentration.

103. The system according to claim 100, wherein the application is industrial minerals mining quality analysis, for determining mineral concentration.

104. The system according to claim 100, wherein the application is cement and concrete preparation, for determining a property selected from the group consisting of sand quality and concentration, gravel quality and concentration, crushed stone quality and concentration, and cement additive quality and concentration.

105. The system according to claim 100, wherein the application is metal fabrication and recycling, for determining metal composition and quality.

106. The system according to claim 100, wherein the application is petrochemical processing, for determining chemical composition.

107. The system according to claim 100, wherein the application is fertilizer manufacturing, for determining chemical composition and mixture quality.

108. The system according to claim 100, wherein the application is paper pulp processing, for determining chemical composition and additive concentration.

109. The system according to claim 100, wherein the application is explosives manufacturing, for determining chemical composition and mixture quality.

110. A security and contraband inspection system for detecting target substances within a subject item comprising:

a gas-target neutron generator to provide neutrons for material analysis of the subject item;

a portable exterior container with radiation shielding to protect an external worker environment and to minimize signal noise to the radiation detector;

a conveyance mechanism to move the subject item past the neutron generator;

a radiation detector situated proximally to the subject item to detect secondary radiation emitted by chemical elements within the subject item upon irradiation by the neutron source; and

an analysis module to receive information from said detector, and to analyze said information to determine chemical elements and their concentrations within the subject item.

111. The system according to claim 110, wherein the gas-target neutron generation is a single-cathode high-pressure high-resistance gaseous discharge neutron generator.

112. The system according to claim 110, wherein the gas-target neutron generator is a double-cathode high-pressure high-resistance gaseous discharge neutron generator.

113. The system according to claim 110, wherein the conveyance mechanism is a conveyor belt.

114. The system according to claim 113, further comprising a long cylindrical high-pressure high-resistance gaseous discharge neutron generator to produce a substantially

linear neutron distribution for substantially uniform conveyor width scanning and detection resolution.

115. The system according to claim 113, further comprising a rectangular prism high-pressure high-resistance gaseous discharge neutron generator to produce a substantially planar neutron distribution for substantially uniform conveyor area scanning and detection resolution.

116. The security inspection system according to claim 110, further comprising a reference database of element combinations and concentrations of target substances for comparison with measured quantities, and a decisional routine to determine whether an element combination and concentration not found in the database library is potentially hazardous.

117. The security inspection system according to claim 110, further comprising a display for showing an image of the subject item superimposed with information related to the composition of a portion of the item whereby a decision can be made to determine whether the object is potentially hazardous.

118. The security inspection system according to claim 110, further comprising an alarm to indicate an alarm condition if the subject item is determined to be potentially hazardous.

119. A method comprising the step of using the security inspection system according to claim 110 for airport luggage inspection.

120. A method comprising the step of using the security inspection system according to claim 110 for parcel and package inspection.

121. The security inspection system according to claim 110, further comprising neutron moderators situated between the neutron generator and the subject item to lower the energy of at least a portion of the incident neutrons.

122. The security inspection system according to claim 110, wherein the detector further comprises an array of energy-sensitive gamma ray detectors for high sensitivity, spatial imaging or detection of prompt and delayed radiation.

123. The security inspection system according to claim 110, wherein the radiation detector is sensitive to neutrons.

124. The security inspection system according to claim 110, further comprising a data logging system for electronic storage and transmission of subject item information for future reference and evaluation.

125. The security inspection system according to claim 124, wherein the data logging system is connected to a central database capable of updating other security inspection systems databases for hazardous or contraband materials.

126. A self-contained portable system for environmental and soil analysis using neutron analysis techniques, comprising:

a gas-target neutron generator system to controllably provide neutrons for the analysis of soil or other environmental media;

a radiation detector situated proximally to the soil or environmental media for collecting secondary radiation caused by the impingement of neutron with the soil or environmental media; and

a data acquisition system to receive information from said detector and to determine properties of the soil or environmental media based on the information from said detector.

127. The soil and environmental on-line analyzer according to claim 126, wherein the neutrons interact with substantially an entire volume of soil or environmental media, providing direct scanning of all the soil or media volume without sampling only a portion of the soil or environmental media.

128. The soil and environmental on-line analyzer according to claim 126, wherein the gas-target neutron generator system comprises a long cylindrical high-pressure high-resistance gaseous discharge neutron generator to produce a substantially linear neutron distribution for substantially uniform wide area soil and media scanning and detection.

129. The soil and environmental on-line analyzer according to claim 126, wherein the gas-target neutron generator system comprises a rectangular prism high-pressure high-resistance gaseous discharge neutron generator geometry to produce a planar neutron distribution for uniform wide area soil and media scanning and detection,

130. The soil and environmental on-line analyzer according to claim 126, further comprising a series of moderating materials situated to slow neutrons to appropriate energies for interaction with the soil or environmental media.

131. The soil and environmental on-line analyzer according to claim 126, further comprising a vehicle platform for movement and mobile analysis.

132. The soil and environmental on-line analyzer according to claim 131, wherein the vehicle platform is remotely controlled and does not require an operator present.

133. A method comprising the step of using the soil and environmental on-line analyzer according to claim 126 for landmine detection, by determining properties typically associated with landmines.

134. A method comprising the step of using the soil and environmental on-line analyzer according to claim 126 for agricultural evaluation and treatment.

135. The soil and environmental on-line analyzer according to claim 126, further comprising a reference database of element combinations and concentrations of target

substances for comparison with measured quantities to determine the likely presence of hazardous material.

136. The soil and environmental on-line analyzer according to claim 131, further comprising a display for showing an image of the soil or media superimposed with information from the analysis system.

137. The soil and environmental on-line analyzer according to claim 126, wherein the gas-target neutron generator is a single-cathode high-pressure high-resistance gaseous discharge neutron generator.

138. The soil and environmental on-line analyzer according to claim 126, wherein the gas-target neutron generator is a double-cathode high-pressure high-resistance gaseous discharge neutron generator.

139. The soil and environmental on-line analyzer according to claim 126 wherein the radiation detector comprises an array of detectors placed proximally to the soil or environmental media for high detection resolution, spatial imaging and detecting prompt and delayed radiation.

140. The system according to claim 126, further comprising an interface to modify a process involving the soil or environmental media based on determined properties of the soil or environmental media.

141. The system according to claim 140, wherein the interface utilizes a configurable software algorithm for evaluating the determined properties of the soil or environmental media and directing a course of action.

142. The system according to claim 126, wherein the radiation detector detects gamma rays.

143. The system according to claim 126, further comprising an exterior container with radiation shielding to protect an external worker environment and to minimize the introduction of signal noise to the radiation detector.

144. A portable medical system for diagnostic imaging and radiation therapy, comprising:

a gas-target neutron generator system to controllably provide neutrons for interaction with a patient;

a moderator to control the neutron energy directed to the patient;

a gamma radiation detector to detect secondary radiation emitted from neutron interaction within the patient; and

a data acquisition system to receive information from said detector and to determine properties of the patient based on the information from said detector.

145. The medical system according to claim 144, wherein the gas-target neutron generator is a single-cathode high-pressure high-resistance gaseous discharge neutron generator.

146. The medical system according to claim 144, wherein the gas-target neutron generator is a double-cathode high-pressure high-resistance gaseous discharge neutron generator.

147. The medical system according to claim 144, wherein the moderator comprises a controllable array of small moderators to create a configurable neutron spatial energy distribution at the patient.

148. The configurable moderator according to claim 147, further comprising a neutron detector array and algorithm to evaluate spatial thermalization characteristics of the patient and to control the moderator array to produce the required neutron energy characteristics.

149. The medical system according to claim 144, wherein the radiation detector comprises an array of energy-sensitive gamma-ray detectors placed proximally to the patient for high

detection resolution, spatial and energy resolution, and for detecting prompt and delayed radiation.

150. The medical system according to claim 144, wherein the gas-target neutron generator system comprises a rectangular prism high-pressure high-resistance gaseous discharge neutron generator to produce a substantially planar neutron distribution for substantially uniform wide area patient irradiation.

151. The medical system according to claim 144, wherein the gas-target neutron generator system comprises a linear cylinder high-pressure high-resistance gaseous discharge neutron generator to produce a substantially linear neutron distribution for substantially uniform patient irradiation.

152. The medical system according to claim 144, wherein the gas-target neutron generator system comprises an annular high-pressure high-resistance gaseous discharge neutron geometry to produce a neutron distribution suitable for substantially annular patient irradiation.

153. The medical system according to claim 144, further comprising neutron-sensitive chemical compounds administered to the patient and resolved through neutron interactions.

154. The bimodal functional medical imaging system according to claim 153, wherein the neutron-sensitive compounds are non-radioactive, selected from the periodic table of elements, such that radiation is emitted from the compounds only upon neutron irradiation.

155. The bimodal functional medical imaging system according to claim 153, wherein the neutron-sensitive chemical compounds administered to the patient is selected to facilitate analysis of one or more metabolic and biological pathways.

156. The bimodal functional medical imaging system according to claim 153, further comprising a cancer detection and evaluation system that uses single photon computed tomography.

157. The bimodal functional medical imaging system according to claim 153, wherein the data acquisition system utilizes a configurable software algorithm for evaluating properties of the patient for use in directing a course of treatment.

158. The bimodal functional medical imaging system according to claim 153, further comprising a mechanism for producing a fused image from an anatomical imaging system.

159. The medical system according to claim 144, further comprises neutron-sensitive drug compounds administered to the patient whereby cancer is treated through neutron interactions with the drug compounds.

160. The bimodal cancer treatment system according to claim 159, wherein the neutron-sensitive drug compounds contain the isotope boron-10 for facilitating a boron neutron capture interaction.

161. The medical system according to claim 144, further comprising an exterior container having radiation shielding to protect an external environment and to minimize the introduction of signal noise to the radiation detector.